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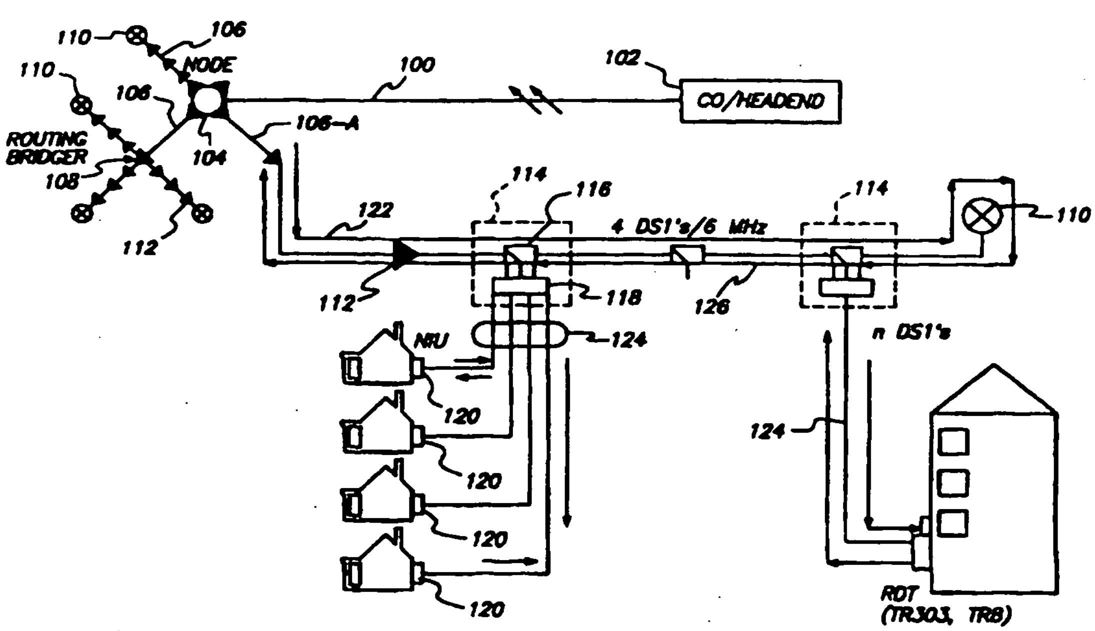

(57) Abstract

A low power, low cost distributed digital loop (DDL) carrier system which combines television and voice telephone signal transmission over coaxial cables. The DDL system employs a passive/active tap module (114) which controls the steering of the video and telephone signals. The high frequency down stream telephone signal is not processed until a routing terminator (110) converts it to a lower frequency signal for transmission in the lower frequency subsplit channel. The telephone signal is then transmitted back up through the subsplit channel where the active circuitry of each tap intercepts the telephone signal, selects the needed signal and transmits it down to a network interface unit (120) located at the subscriber premises.

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DISTRIBUTED DIGITAL LOOP CARRIER SYSTEM USING COAXIAL CABLE

This invention relates to communication systems.

Cable television (CATV) systems typically comprise a coaxial cable which carries signals downstream in the frequency range 50-1000 MHz (referred to as the "supersplit" channel) and upstream in the frequency range 5-50 MHz (referred to as the "subsplit" channel). At intervals along the coaxial cable, there are directional signal couplers (referred to as "taps"). Each tap provides an outlet to several subscribers, enabling each subscriber to access the downstream signal and to inject upstream signals. The system also includes amplifiers, typically placed after every five to ten taps.

If telephone service is also carried on the coaxial cable, the downstream telephone signals are usually carried in the supersplit channel and upstream telephone signals in the subsplit channel. For each subscriber, a telephony box containing modulator-demodulators (modems) is placed at a tap, and the subscriber's telephone is connected to the telephony box by a twisted pair.

CATV systems carrying telephone services suffer from a number of problems, in particular:

(1) Telephone service can be interrupted for unacceptably long periods when new taps are added for new CATV customers. This involves cutting the cable, and often requires adjustment of the tap ratios downstream from the new tap.

(2) The telephony boxes are expensive.

(3) Noise enters the CATV system from the drop cable and equipment at the subscriber's premises, and is amplified as it moves upstream, and interferes with upstream signals.

(4) Power to operate the telephony boxes must be transmitted down the cable.

(5) A preferred method of transmitting data is time division multiplexing (TDM). However, combined CATV and telephone systems which use TDM suffer from the so-called "ranging" problem. The ranging problem arises because the twisted pairs

which connect different subscribers to the taps on the coaxial cable have different lengths. This fact makes it difficult and expensive to achieve the very precise timing of the inputs from the subscribers which is necessary in TDM.

We have discovered that these problems can be mitigated through the use of a routing terminator which is placed at the downstream end of a CATV or other coaxial cable, and which converts downstream relatively high frequency signals, e.g. the telephone signals in a combined video and telephone signal in a supersplit channel, into relatively low frequency signals, and transmits the low frequency signals upstream on the coaxial cable, e.g. low frequency telephone signals, in a subsplit channel of the coaxial cable.

Accordingly, in one aspect, this invention provides a communication system which comprises:

a. a coaxial cable having an upstream end and a downstream end; and

b. a routing terminator which

   (1) is connected at the downstream end of the coaxial cable,

   (2) can convert a relatively high frequency downstream signal from the coaxial cable into a relatively low frequency signal, and

   (3) can transmit the relatively low frequency signal upstream on the coaxial cable.

Preferred systems of the invention can provide an improved CATV system and include

a. a plurality of taps, placed at spaced locations along the coaxial cable and coupled with the coaxial cable, each tap comprising

   (1) a passive module,

   (2) an active distribution unit, and

   (3) means for coupling and decoupling the passive module with the active distribution unit;

b. a plurality of network interface units each network interface unit being located at a subscriber premises; and

c. a plurality of drop cables, each drop cable having a first end coupled with a tap and a second end coupled with a network interface unit.

In these preferred systems, the passive module can extract downstream video signals from the supersplit channel and upstream telephone signals from the subsplit channel, and pass the extracted signals to the active distribution unit. The active distribution unit can combine the extracted video and telephone signals, and transmits, the combined signal to the network interface unit located on the subscriber's premises. The active distribution unit can also receive a combined subsplit signal comprised of outgoing video control and telephone signals from the network interface unit, and transmit the combined subsplit signal onto the coaxial cable in the subsplit channel.

In these preferred systems, data is transmitted using a synchronous data transmission format such as time division multiplexing.

In a second aspect, this invention provides a distributed communication system which comprises:

a. a central office;

b. a plurality of communication systems according to the first aspect of the invention, the coaxial cable of each of the communication systems having an upstream end coupled to the central office.

In a third aspect, this invention provides a method of providing combined telephone and video signal communications via a coaxial cable, the method comprising the steps of:

a. dividing a frequency spectrum of a coaxial cable into a low frequency subsplit channel and a high frequency supersplit channel;

b. transmitting combined video and telephone signals, in the supersplit channel, in a first direction from a central office end toward a coaxial cable termination;

c. tapping of a predetermined portion of the video portion of the signal for transmission to subscribers;

d. amplifying the predetermined portion of the video portion to generate an amplified to-subscriber video signal;

e. converting, at a coaxial cable termination, a telephone portion of the combined video and telephone signals to a lower frequency telephone signal suitable for transmission in the subsplit channel, the converting comprising the steps of

(1) separating the telephone signal portion from the combined telephone and video signals being transmitted in the supersplit channel,

(2) demodulating the telephone signal,

(3) reconstructing the telephone signal to improve the signal to noise ratio of the telephone signal, and

(4) remodulating the reconstructed telephone signal using the lower frequency suitable for transmission in the subsplit channel;

f. transmitting the lower frequency telephone signal in the subsplit channel in a second direction from the coaxial cable termination back toward the central office end;

g. tapping off the lower frequency telephone signal being transmitted in the subsplit channel for transmission to subscribers;

h. demodulating and selecting an appropriate portion of the tapped off lower frequency telephone signal to generate a to-subscriber telephone signal;

i. combining the to-subscriber video signal and the to-subscriber telephone signal into a single combined to-subscriber video and telephone signal; and

j. transmitting the single combined to-subscriber video and telephone signal to a subscriber via a drop cable.

In a fourth aspect, this invention provides a routing terminator which is suitable for use in the first, second and third aspects of the invention and which comprises:

a. coupling means for coupling the routing terminator at a downstream end of a coaxial cable;

b. filter means for filtering and receiving a portion of a downstream signal;

c. demodulation and repeating means for demodulating and repeating a received portion of the downstream signal to generate an output signal

having a larger signal to noise ratio than the received portion of the downstream signal; and

d. modulation means for converting the demodulated and repeated received portion of the downstream signal to a low frequency upstream signal.

In a fifth aspect, this invention provides a network interface unit which is suitable for use in the preferred embodiments of the first, second and third aspects of the invention and which comprises:

a. coupling means for coupling the network interface unit to a drop cable;

b. first bandsplit filter means for

(1) receiving a combined signal from an active distribution unit via the drop cable, and

(2) separating an amplified extracted portion of a downstream signal and a predefined portion of an extracted portion of an upstream signal;

c. transmission means for

(1) transmitting the predefined portion of the extracted portion of the upstream signal to subscriber telephone equipment, and

(2) transmitting the amplified extracted portion of the downstream signal to subscriber video equipment;

d. reception means for

(1) receiving a new telephone signal from subscriber telephone equipment, and

(2) receiving a video control signal from subscriber video equipment;

e. second bandsplit filter means for

(1) combining the new telephone signal and the video control signal to form a combined subsplit signal, and

(2) transmitting the combined subsplit signal to the active distribution unit via the drop cable; and

f. control means for

(1) controlling receipt of a telephone signal being transmitted to the subscriber telephone equipment, and

(2) controlling transmission of the new telephone signal received from the subscriber telephone equipment.

In a sixth aspect the invention provides a routing bridger which is suitable for use in a distributed communication system according to the second aspect of the invention and which comprises:

a. feeder band split filter means for
   (1) receiving a high frequency signal from a feeder coaxial cable, and
   (2) transmitting a low frequency signal to the feeder coaxial cable;
b. branch band split filter means for
   (1) transmitting the high frequency signal to a plurality of network branches, and
   (2) receiving a low frequency signal from each of the plurality of network branches;
c. data identifier means for
   (1) identifying timing information for each of the plurality of low frequency signals received from the plurality of network branches, and
   (2) generating a control signal for each low frequency signal;
d. control means for combining the plurality of low frequency signals received from the plurality of network branches into a single signal in response to the control signals generated by the data identifier means.

The present invention is of particular value for CATV systems which provide video and telephone service, and will, therefore, be described chiefly by reference to such CATV systems. It is to be understood, however, that the invention can also be used for other communication systems.

The CATV systems of the invention are distributed digital loop (DDL) systems in which each of the taps comprises a passive module (PM) and an active distribution unit (DU) which can be coupled or decoupled to the PM, and which is preferably physically detachable from the PM. When the DU is decoupled from the PM, the PM preferably

allows the signals to pass through it with very low loss. When the DU is coupled to the PM, the PM extracts signals from the cable and the DU processes the signals and passes them to one of several, e.g., four, cable drops, each of which is coupled to a network interface unit (NIU) located at a subscriber's premises.

The PM preferably comprises:

a. a downstream extraction means;

b. an upstream extraction means;

c. coupling means which, when the passive module is coupled with the active distribution unit,

 (1) couples the downstream extraction means with the downstream signal, the downstream extraction means then extracting a portion of the downstream signal and diverting the extracted portion of the downstream signal to the active distribution unit, and

 (2) couples the upstream extraction means with the upstream signal, the upstream extraction means then extracting a portion of the upstream signal and diverting the extracted portion of the upstream signal to the active distribution unit; and

d. decoupling means which, when the passive module is decoupled from the active distribution unit,

 (1) decouples the downstream extraction means from the downstream signal on the coaxial cable, and

 (2) decouples the upstream extraction means from the upstream signal on the coaxial cable.

The DU preferably comprises:

a. demodulation means for demodulating the extracted portion of the upstream signal;

b. selection means for selecting a predefined portion of the extracted portion of the upstream signal;

c. first amplification means for amplifying the extracted portion of the downstream signal;

d. filter means for combining the amplified extracted portion of the downstream signal and the predefined portion of the extracted portion of the upstream signal and placing the combined signal on the drop cable;

e. monitor means for testing a functionality of the network interface unit by examining the integrity of a combined subsplit signal received from the network interface unit;

f. bypass means for bypassing a connection to the network interface unit if the network interface unit is malfunctioning;

g. modulation means for modulating the received combined subsplit signal; and

h. second amplification means for amplifying and transmitting the combined subsplit signal onto the coaxial cable.

The NIU preferably comprises:

a. first bandsplit filter means for
   (1) receiving the combined signal from the active distribution unit via the drop cable, and
   (2) separating the amplified extracted portion of the downstream signal and the predefined portion of the extracted portion of the upstream signal;

b. transmission means for
   (1) transmitting the predefined portion of the extracted portion of the upstream signal to subscriber telephone equipment, and
   (2) transmitting the amplified extracted portion of the downstream signal to subscriber video equipment;

c. reception means for
   (1) receiving a new telephone signal from subscriber telephone equipment, and
   (2) receiving a video control signal from subscriber video equipment;

d. second bandsplit filter means for
   (1) combining the new telephone signal and the video control signal to form a combined subsplit signal, and

(2) transmitting the combined subsplit signal to the active distribution unit via the drop cable; and

e. control means for

(1) controlling receipt of the predefined portion of the extracted portion of the upstream signal being transmitted to the subscriber telephone equipment, and

(2) controlling transmission of the new telephone signal received from the subscriber telephone equipment.

The DU amplifiers provide automatic gain control which eliminates the need to reconfigure taps for use at different signal level points on the cable. This arrangement minimizes system unavailability during tap insertions, maintenance, or circuit failures, and permits the sharing of signal access electronics by several subscribers to save power and cost. In addition the passive taps may be preinstalled on the cable since the bypassing mechanism allows the signal to pass undisturbed. Moreover, when it is necessary to cut a cable to install a new tap, it is possible to temporarily route around the location being cut by making a connection from an upstream tap to a downstream tap.

Further reductions in power consumption and cost are made possible by the use of the routing terminator (RT). The DDL system is designed to allow each tap to extract a portion of the high frequency signal as the signal is transmitted downstream. The extracted video signal is subsequently processed while the high frequency telephone signal remains unprocessed. Once the telephone signal reaches the end of the cable, the RT receives the signal and demodulates the signal down to digital baseband. The RT processes the digital signal and reconstructs the signal as a substantially noise-free signal. The RT then remodulates the reconstructed digital signal with a carrier frequency in the subsplit channel. The RT transmits the lower frequency telephone signal upstream in the subsplit channel. Thus, all active telephone electronics along the upstream signal path operate at lower frequencies, and thus results in reduced cost and power consumption. Also, since the return subsplit signal is repeated and the downstream video signal is less attenuated by each DU, the system requires fewer amplifiers along the transmission channel compared to a conventional distribution approach.

As the signal travels upstream in the subsplit channel, each DU intercepts the entire telephony signal, selects out the data intended for one or more local subscribers, and transmits the selected signal down to the appropriate NIU. A coaxial cable hybrid circuit allows communication between the DU and NIU over the coaxial drop at the digital baseband frequency. Upon receipt of the data, the NIU reads the data in and replaces incoming data with outgoing data in a drop-and-insert fashion. The DU then places the outgoing data into the same time slot of the data stream and rebroadcasts the outgoing data upstream in the subsplit channel.

The use of the DUs at each tap location eliminates the ranging problem since each DU receives the entire digital signal from the feeder coaxial cable. The DUs are all located the same distance from the coaxial cable, i.e. typically about an inch, and the timing requirements are therefore easily calculated. This enables the use of synchronous transmission systems such as time division multiplexing.

The DDL system of this invention reduces the susceptibility to noise by operating at relatively low frequencies, e.g. in the range of 2 MHz on the drop cable, and providing circuitry in the DU to filter out noise in that range.

The DDL system of this invention can make use of the novel routing bridger according to the sixth aspect of the invention to manage signal traffic at the intersection of several branches of a CATV network. The valid time slots are different for the signals arriving at the bridger from its different legs. The routing bridger includes circuitry to determine which time slots are valid from each leg, to recompose the returned signal into a fresh frame, and to transmit the signal back to the optic/electric node or other signal source.

In use of the present invention, it may be necessary or convenient to place the DU, or other electronics in relatively small subsystems located outdoors. It is preferred to use secure and flexible environmental protection for all such components. Such environmental protection is preferably reentrable and replaceable. Copending, commonly assigned International Application PCT/US95/04291 discloses an environmental protection apparatus comprising a flexible environmental gas and liquid barrier envelope capable of

accepting an active electronics circuit board, the envelope completely sealed around the active electronics board; and an interconnection device sealed to the envelope which contains the active electronic printed circuit board and also permitting the connection of the active electronics board into an electronics system. Preferred embodiments include a flexible metal layer sandwiched between flexible plastic films. The disclosure of International Application PCT/US95/04291 is incorporated herein by reference for all purposes.

Figure 1 is a top level diagram illustrating the overall architecture of the distributed digital loop (DDL) carrier system. A main fiber optical feeder cable 100 connects a central office (or head) end 102 to an optic/electric node 104. The optic/electric node 104 provides for optical to electrical (and electrical to optical) conversion and broadcasts the electrical signal throughout the system via coaxial cables 106. A routing bridger 108 allows the branching of a single cable into several, for example three, legs. Each leg includes numerous amplifiers 112 which provide for signal amplification in both directions. A routing terminator (RT) 110 terminates each leg of the network.

Figure 1 further shows components of the system along one branch 106-A of the network. Passive/active taps 114 are provided along branch 106-A to provide for subscriber access to the signal. Amplifiers 112 are placed between every few taps 114 to amplify the signal as it travels along the cable. Each tap 114 includes an in-cable passive module (PM) 116 and a detachable active distribution unit (DU) 118. The DU 118 connects via separate cables such as coaxial or other types of drop cables 124 to several (in this example four) different network interface units (NIUs) 120 which are located at the subscriber premises.

In operation, the frequency spectrum of the coaxial cable is conventionally divided at around 50 MHz to separate the downstream or supersplit channel 122 (50 MHz to 1000 MHz) from the upstream or subsplit channel 126 (5 MHz to 50 MHz). Voice telephone signals can be simultaneously transmitted downstream in any frequency channel which is unused by the CATV signals. In this exemplary embodiment, four DS1's (i.e., 96 voice

channels using the North American standards) inside a 6 MHz band at around 700 MHz facilitate transmission of voice telephone signals in the downstream direction.

The downstream channel 122 thus carries both the high frequency video and telephone signals. As the signal travels down the channel 122, a directional coupler inside each tap 114 slices a portion, for example 1/3 of the signal (approximately 10dB down from the total energy), of the video signal and transmits it down to the NIUs 120 via drop cables 124. The high frequency, broadband modulated telephone signal, however, passes through each tap 114 without further processing until it reaches the RT 110.

The RT 110 demodulates the analog telephone signal to baseband digital signal and regenerates the digital signal to eliminate accumulated noise. The RT 110 then remodulates the signal using a lower frequency (e.g., 18 or 20 MHz) suitable for the subsplit channel as the carrier frequency, and transmits the signal upstream through the subsplit channel 126. As the telephone signal travels up the subsplit channel 126, a diplexer inside each tap 114 diverts the telephone signal to the active circuitry of the DU 118. The DU 118 demodulates the signal and selects the right DS1 for the attached subscribers. Then, the DU 118 converts the signal into a baseband signal by performing, for example, simple line coding techniques. Because of the short distances, simple line coding techniques such as Manchester coding or alternate mark inversion (AMI) can be used effectively.

The DU 118 then combines the baseband signal with DC power and downstream video signal and transmits the combined signal down through the first drop cable 124 to the first NIU 120. Upon receipt of the signal, the NIU 120 unloads and loads its channel(s) (voice time slots) also using line coding, and then passes the signal back up the drop using a hybrid circuit for coaxial cables. The DU 114 amplifies and remodulates the signal again and transmits it back down to the next NIU 120 on another drop cable 124. This process continues until all (in this example four) attached NIUs 120 have been passed.

Tap

Figure 2A shows one embodiment of the tap 114 of Figure 1. It includes the PM 116 and the DU 118. The PM 116 includes a directional coupler 200 and a diplexer 202. The directional coupler 200 is a transformer-based splitter which splits off a signal between 10 and 15dB down from the total energy of the video signal and directs the split-off signal down toward the DU 118. The remaining portion of the video signal, as well as the high frequency telephone signal, continue to travel downstream (from left to right in Figure 2A). The diplexer 202 includes a high pass filter 204 in the downstream direction to pass through the high frequency signal, and a low pass filter 206 in the upstream direction which directs the low frequency subsplit signal toward the DU 118. Inductors 208 allow 60Hz power to pass through the tap in both directions and to the DU 118. Both the directional coupler 200 and the diplexer 202 require coils of very fine wire. Capacitors 210 are provided to protect these devices from potential damage caused by low frequency overcurrents. The PM 116 inserts a small and predictable amount of loss of approximately 1dB in the signal path.

The PM 116 permits continuous flow of upstream signal along the cable 106 even when the DU 118 is detached. A bypass switch 212 is connected across the diplexer 202, coupling the output of the low pass filter 206 to the downstream input of the diplexer 202. The bypass switch 212 is activated when the DU 118 is detached from the passive coupler 116, allowing the upstream signal to flow through the tap. Alternatively, the bypass switch 212 could be connected across the output of the high pass filter 204 and the downstream input of the diplexer 202, thus also bypassing the DU 118 for the upstream signal. The bypass switch 212 is preferably a diode switch activated by a contact signal 214, but can also be an electromechanical relay or a mechanically activated switch.

Figure 2B shows a second embodiment of the tap in which the PM 116 includes a single inductor 208 for passing the 60Hz power signal, and the bypassing switch 212, with both connected across the tap to bypass the DU 118. The directional coupler 200 and diplexer 202 are placed inside the DU 118. Again, the bypassing function may be implemented using electronic or mechanical devices.

Routing Terminator

Figure 3 shows a block diagram of a preferred embodiment of the routing terminator (RT) 110. The RT 110 converts the high frequency downstream telephone signal to a lower frequency suitable for transmission in the subsplit channel 126, and also includes circuitry for noise reduction.

The RT 110 includes a band split filter 300 which (i) receives the downstream signal from the coaxial cable, (ii) extracts the 60Hz power signal from the downstream signal, (iii) applies the power signal to a power conversion circuit 302 to obtain DC power, and (iv) combines the received high frequency downstream signal and the transmitted low frequency subsplit signal. It may also perform other functions such as error checking and sending alarm signals. The band split filter 300 includes a video signal termination resistor 304 of approximately 75W to reduce video signal reflection.

The filtered high frequency downstream signal is applied to a tuner/demodulator 306 which is programmed to tune to the specific frequency of the telephone signal, which in this example is set at around 700 MHz. The demodulator demodulates the signal to baseband using one or more stages of demodulation. The digital signal is applied to a detect circuit 308, a framing circuit 310 and a quality monitor circuit 312. The detect circuit 308 detects the four downstream DS1 signals, while the framing circuit 310 extracts the framing information for each signal. The quality monitor circuit 312 monitors the bit error rate and the signal eye pattern to determine signal quality. The outputs of these three circuits feed into a control circuit 314 which reshapes and repeats the digital signal to remove noise and restore signal quality. The output of the control circuit 314 goes through a modulator 316 which modulates the digital signal using a subsplit frequency, for example 18 MHz, as the carrier frequency. The modulated subsplit signal is then applied to an input of the band split filter 300 to be placed back on the coaxial cable. Thus, the RT 110 converts the high frequency telephone signal to a low frequency signal and improves the available signal to noise ratio. This signal is then transmitted upstream and intercepted by the first DU 118.

Figure 4 illustrates the spectral management of the DDL system. The 50 MHz frequency marks the separation between the downstream and upstream signals. Telephone signals are transmitted downstream within several 6 MHz frequency bands each carrying, for example, four DS1s. These signals are transmitted at around, for example, 700 MHz, a frequency typically unused for video transmission. The RT 110 shifts the frequency of the downstream digital package (e.g., four DS1's) down to around, for example, 18 MHz within the subsplit channel as shown. The subsplit upstream signal also carriers video management signals which must be assigned outside the band of frequencies used for the telephone signal.

Distribution Unit

The high frequency downstream telephone signal travels the entire length of the cable through numerous taps without being intercepted. Once converted to low frequency and transmitted up the subsplit channel, however, the signal is diverted by the diplexer 202 in each tap 114 (Figure 2A) to the DU 118. Figure 5 (Figures 5A and 5B) shows the block diagram for the DU 118 as used in the embodiment for the tap module 114 shown in Figure 2A. Two separate signals are supplied to the DU 118: the high frequency downstream video signal from the directional coupler 200, and the subsplit DS1 signal from the diplexer 202. The subsplit DS1 is first demodulated by a demodulator 500 which also extracts the clock signal for synchronous operation. To save expensive framer devices, in one embodiment, the signal formatter/modulator used at the source of the DDL system reformats the framing pulse of each DS1 into a specially recognizable data pulse by making the framing pulse larger than normal data pulses. This reformatted large framing pulse is easily detected by a framing pulse detect block 501 inside the DU 118.

A microprocessor 502 receives the DS1 framing information and the extracted clock signal, while a DS1 select block 504 receives the demodulated DS1 signal. The microprocessor 502 receives system control information from the central office 102 (Figure 1) in a dedicated time slot. A SEL_DS1 control signal is generated by the microprocessor 502 and, in response to assignment control information from the central office 102, is applied to DS1 select block 504 to select the particular DS1 intended for the local NIU. A first NIU signal processing block 506 receives the selected DS1, while the

unselected DS1s are fed into a delay adjust buffer 508. The NIU signal processing block 506 selects the appropriate DS1 signal and routes the signal to the first NIU, NIU_A. The DU 118 further includes three other essentially identical NIU signal processing blocks 506 which are serially connected to the first NIU signal processing block 506 to service four local NIUs, NIU_A, NIU_B, NIU_C, and NIU_D.

The NIU signal processing block 506 includes a data/control block 510 which combines the selected DS1 with NIU control bits for the attached NIU. The NIU control bits are provided by the microprocessor 502 which translates incoming configuration information into a special NIU set-up message consisting entirely of the special data pulse format (i.e., larger pulses). The combined signal then goes through a hybrid circuit 512 that in addition to performing the normal hybrid function, performs simple line coding on the DS1 signal (1.544 MHz in North America) to convert the signal down to baseband. The hybrid circuit 512 uses preferably Manchester coding, although other line coding techniques such as alternate mark inversion or HDB3 can also be used. The line coded combined DS1 and NIU control signal is applied to a band split filter 514 which combines the low frequency baseband telephone signal with the high frequency downstream video signal. The video signal from the directional coupler 200 is first amplified by an amplifier 516. The video signal then goes through a slope and gain equalizing circuit 518 and is then applied to the band split filter 514. The combined signal is transmitted via the coaxial cable drop down to the first NIU, i.e. NIU_A. A current limiting circuit 519 also connects to the band split filter 514 to limit the amount of current flowing through cables that are exposed to the subscribers. Note that since the DU 118 may optionally amplify both the video and the telephone signals going to the subscriber, the tap ratios of all tap modules can be made the same. This simplifies the network design and reduces the number of amplifiers along the cable.

The return subsplit signal from the NIU includes telephone signal as well as subsplit video tones. The band split filter 514 receives the return signal and separates the subsplit video tones at an output SA. The band split filter also helps remove most of the upstream interfering signal ingress and improves reliability and quality of the telephony subsystem. The return telephone signal goes back through the hybrid circuit 512, which

separates the transmit and receive signals, and is applied to an NIU monitor logic 520. The NIU monitor logic 520 checks the functionality of the attached NIU by monitoring the number and location of the time slots allocated to that NIU. An output signal NIU_A_OK indicates whether the attached NIU_A is functional. This signal is applied to the microprocessor 502 which generates an NIU_A_BYPASS signal in response. The NIU_A_BYPASS signal is applied as a control signal to a multiplexer 522. The two inputs to the multiplexer 522 are the return telephone signal at the output of the NIU monitor logic 520, and the output of the DS1 select block 504. Thus, when NIU monitor logic 520 determines that the attached NIU_A is faulty, NIU_A_BYPASS is asserted, and the selected DS1 is coupled to the output of the multiplexer bypassing the first NIU_A.

The selected DS1 continues to travel through the remaining NIU signal processing blocks 506 in a serial fashion, servicing all attached NIUs. The signal is then recombined with the delay adjusted unselected DS1s by a DS1 combine block 524. The DS1 combine block 524 uses the extracted clock information and the SEL_DS1 signal from the microprocessor 502 to form the complete upstream DS1 signal at its output. The upstream DS1 signal is combined with the subsplit video signal received from the local NIUs, and modulated by modulator 526. The video subsplit signals SA, SB, SC, and SD are first added by an adder circuit 528, then pass through a band eliminate filter 530, and applied to the modulator 526. The band eliminate filter 530 removes extraneous signal energy that would interfere with the modulated telephone signal. The subsplit signal at the output of the modulator 526 is amplified by an amplifier 532 and then reinserted into the coaxial distribution cable via a directional coupler 534. The addition of a small net gain to the subsplit signal eliminates the need for separate upstream amplifiers along the cable.

<u>Network Interface Unit</u>

Figure 6 is a block diagram of the single-line NIU 120. The NIU 120 includes a band split filter 600 whose input terminal couples to the coaxial drop cable connector 602. The band split filter 600 filters out the downstream video signal and directs the signal to a video coax connector 604 which is connected to a television set-top converter by the subscriber. The filtered DS1 signal is fed to a special DS1 hybrid circuit 606 which manages the two-way traffic between the transmit and receive signals.

The hybrid circuit 606 is capable of transmitting signals in both directions on the same baseband frequency. This is accomplished by transmitting and receiving (across an impedance) at both ends of the drop cable at the same time. At each end circuits read the total signal on the line and then subtract the signal being transmitted from the same end. This type of circuit is commonly used in the transmission of duplex signals on a single twisted pair but is not ordinarily used on coaxial cables. Because active electronics are provided at both ends of the drop cable 602, this power efficient hybriding function can be employed by the NIU 120. The DS1 hybrid circuit 606 also decodes the line coded signal to recover the DS1 signal before applying it to a line circuit 608.

The line circuit 608 includes a standard "combo" filter-codec device 614 which converts the selected channel (DS0) of the DS1 signal into a voice band signal. The voice band signal is then coupled to subscriber tip and ring wires via a conventional hybrid circuit 616 and transformer 618. The line circuit 608 further includes a battery feed for the transformer 618, protection circuitry 620 coupled to the tip and ring terminals, and a low-power DC to AC ring generator 622.

The NIU also includes a provisioning circuit 610 which receives the time slot assignment(s) for the attached subscriber from a frame detect circuit 612. The provisioning circuit 610 includes a configuration register which stores time slot allocations, testing and other command bits for the NIU. The registered time slot assignments for the NIUs are previously remotely configured via a block of data consisting of the special (i.e., large) pulses following a framing pulse. The provisioning circuit 610 further includes time slot select logic and line test logic which communicate with the combo device 614 and line test relay 624.

The outgoing speech is coded by the combo device 614 and placed in the same time slot as that of the received DS1 signal. The DS1 hybrid 606 inserts the contents of the NIU configuration register in place of the new control bits for the outgoing signal to allow for NIU monitoring by NIU monitor logic 520 in the DU 118 (Figure 5). The outgoing signal

is then combined with subsplit video control signals by the band split filter 600 and returned to the DU 118 via the same coax drop as the arriving signal.

The interface to the DDL system is not limited to the single-line POTS embodiment of the NIU described above. The NIU can be, for example, any one of a basic POTS interface device, SLC-96 socket emulator for provision of special services, ISDN interface device, or DS0 or DS1 extender. The only requirements for any type of NIU used in the DDL system are the interface to the serving coax drop cable, and the drop-and-insert method by which receive and transmit signals are processed.

Routing Bridger

Referring back to Figure 1, the routing bridger 108 receives the downstream RF signal from the optic/electric node 104 and broadcasts the signal to several legs. As discussed above, the routing terminator 110 in each leg repeats and translates the voice bundle into its subsplit allocation and sends the voice bundle back upstream. As the upstream signal travels along the subsplit, various time slots in the voice bundle are replaced by the DU/NIU elements on each leg. Thus, the signal arriving at the routing bridger 108 is different for each leg, with different time slots being valid from each leg. The routing bridger 108, therefore, must be capable of determining which time slots are valid from each leg to properly steer the time slots in the return direction. To accomplish this task, the routing bridger 108 takes advantage of the fact that messages from the head end to peripheral devices (e.g., DUs and NIUs) are acknowledged as executed or received. The DDL system employs the synchronous data link control (SDLC) protocol for data communications. SDLC is based on a zero-bit-insertion algorithm, similar to CCITT's high level data link control (HDLC), except it contains a special poll flag for loop operation. The poll flag is sent out by the head end via the SDLC common data channel to the peripheral devices. The peripheral devices confirm the receipt of a message by modifying the poll flag. Thus, by decoding the data channel between the head end and the peripheral devices and examining the poll flag, the routing bridger 108 can identify the valid time slots from each leg.

Figure 7 is a diagram of one embodiment of the routing bridger. The downstream signal received on the coax cable connecting the routing bridger 108 to the optic/electric node 104 is applied to a bandsplit filter 800. The high frequency downstream signal at the output of the bandsplit filter 800 is amplified and equalized by amplifier/equalizer 802. The signal is then simultaneously applied to inputs of three bandsplit filters 804, each coupled to a separate leg. The high frequency RF signal is thus broadcast to all legs of the network connected to the routing bridger 108.

The return subsplit signal from each leg is separated from the high frequency downstream signal by bandsplit filters 804. The subsplit signal from each leg is separately decoded by decoders 806. The decoded signal is applied to a data detect block 808 which detects the framing information (LA_FRAME, LB_FRAME, and LC_FRAME) and data (LA_DATA, LB_DATA, and LC_DATA) for the signal in each leg. The detected data is then applied to an SDLC block 810 which examines the SDLC data and generates a control signal (LA_CONT, LB_CONT or LC_CONT). The control signals are then applied to a bridger control logic 812. A multiplexer/buffer 814 receives the framing and data information from each leg, as well as the output of the control logic 812. Based on the SDLC control signals, the multiplexer/buffer 814 recomposes the return subsplit signals into a fresh frame. Thus, when a DU 118 agrees to use time slot X for one of its NIUs, the routing bridger 108 can instantly allocate this time slot to the leg on which the message appeared.

CLAIMS

1. A communication system which comprises:
   a. a coaxial cable having an upstream end and a downstream end; and
   b. a routing terminator which
      (1) is connected at the downstream end of the coaxial cable,
      (2) can convert a relatively high frequency downstream signal from the coaxial cable into a relatively low frequency signal, and
      (3) can transmit the relatively low frequency signal upstream on the coaxial cable.

2. A system according to claim 1 wherein the downstream signal comprises video and telephone signals in a supersplit channel, and the upstream signal comprises telephone signals in a subsplit channel.

3. A system according to claim 1 or 2 which comprises:
   a. a plurality of taps, placed at spaced locations along the coaxial cable and coupled with the coaxial cable, each tap comprising
      (1) a passive module,
      (2) an active distribution unit, and
      (3) means for coupling and decoupling the passive module with the active distribution unit;
   b. a plurality of network interface units each network interface unit being located at a subscriber premises; and
   c. a plurality of drop cables, each drop cable having a first end coupled with a tap and a second end coupled with a network interface unit.

4. A system according to claim 3 wherein the routing terminator comprises:
   a. filter means for filtering and receiving a portion of the downstream signal;
   b. demodulation and repeating means for demodulating and repeating the received portion of the downstream signal to generate an output signal

having a larger signal to noise ratio than the received portion of the downstream signal;

c. modulation means for converting the demodulated and repeated received portion of the downstream signal to the low frequency upstream signal.

5. A system according to claim 3 or 4 wherein the passive module comprises:

a. a downstream extraction means;

b. an upstream extraction means;

c. coupling means which, when the passive module is coupled with the active distribution unit,

(1) couples the downstream extraction means with the downstream signal, the downstream extraction means then extracting a portion of the downstream signal and diverting the extracted portion of the downstream signal to the active distribution unit, and

(2) couples the upstream extraction means with the upstream signal, the upstream extraction means then extracting a portion of the upstream signal and diverting the extracted portion of the upstream signal to the active distribution unit; and

d. decoupling means which, when the passive module is decoupled from the active distribution unit,

(1) decouples the downstream extraction means from the downstream signal on the coaxial cable, and

(2) decouples the upstream extraction means from the upstream signal on the coaxial cable.

6. A system according to any one of claims 3 to 5, wherein the active distribution unit comprises:

a. demodulation means for demodulating the extracted portion of the upstream signal;

b. selection means for selecting a predefined portion of the extracted portion of the upstream signal;

c. first amplification means for amplifying the extracted portion of the downstream signal;

d. filter means for combining the amplified extracted portion of the downstream signal and the predefined portion of the extracted portion of the upstream signal and placing the combined signal on the drop cable;

e. monitor means for testing a functionality of the network interface unit by examining the integrity of a combined subsplit signal received from the network interface unit;

f. bypass means for bypassing a connection to the network interface unit if the network interface unit is malfunctioning;

g. modulation means for modulating the combined subsplit signal; and

h. second amplification means for amplifying and transmitting the combined subsplit signal onto the coaxial cable.

7. A system according to any one of claims 3 to 6 wherein the network interface unit comprises:

a. first bandsplit filter means for

(1) receiving the combined signal from the active distribution unit via the drop cable, and

(2) separating the amplified extracted portion of the downstream signal and the predefined portion of the extracted portion of the upstream signal;

b. transmission means for

(1) transmitting the predefined portion of the extracted portion of the upstream signal to subscriber telephone equipment, and

(2) transmitting the amplified extracted portion of the downstream signal to subscriber video equipment;

c. reception means for

(1) receiving a new telephone signal from subscriber telephone equipment, and

(2) receiving a video control signal from subscriber video equipment;

d. second bandsplit filter means for

(1) combining the new telephone signal and the video control signal to form a combined subsplit signal, and

(2) transmitting the combined subsplit signal to the active distribution unit via the drop cable; and

e. control means for

(1) controlling receipt of the predefined portion of the extracted portion of the upstream signal being transmitted to the subscriber telephone equipment, and

(2) controlling transmission of the new telephone signal received from the subscriber telephone equipment.

8. The system as claimed in any one of claims 1 to 7 wherein data is transmitted using a synchronous data transmission format such as time division multiplexing.

9. A distributed communication system which comprises:

a. a central office; and

b. a plurality of communication systems as claimed in any of claims 1 to 8, the coaxial cable of each communication system having an upstream end coupled to the central office.

10. A signal tap apparatus suitable for use in a system as claimed in any of claims 3 to 8 and comprising:

a. a passive module; and

b. an active distribution unit;

the passive module comprising

(1) means for coupling the passive module to a coaxial cable;

(2) means for passing a power signal through the passive module;

(3) a downstream extraction means;

(4) an upstream extraction means;

(5) coupling means which, when the passive module is coupled with the active distribution unit,

(a) couples the downstream extraction means with the downstream signal, the downstream extraction means then extracting a portion of the downstream signal and diverting the extracted portion of the downstream signal to the active distribution unit, and

(b) couples the upstream extraction means with the upstream signal, the upstream extraction means then extracting a portion of the upstream signal and diverting the extracted portion of the upstream signal to the active distribution unit; and

(6) decoupling means which, when the passive module is decoupled from the active distribution unit,

(a) decouples the downstream extraction means from the downstream signal on the coaxial cable, and

(b) decouples the upstream extraction means from the upstream signal on the coaxial cable; and

the active distribution unit comprising

(1) demodulation means for demodulating the extracted portion of the upstream signal;

(2) selection means for selecting a predefined portion of the extracted portion of the upstream signal;

(3) first amplification means for amplifying the extracted portion of the downstream signal;

(4) filter means for combining the amplified extracted portion of the downstream signal and the predefined portion of the extracted portion of the upstream signal and placing the combined signal on a drop cable;

(5) monitor means for testing a functionality of a network interface means by examining the integrity of a combined subsplit signal;

(6) bypass means for bypassing a connection to the network interface unit if the network interface unit is malfunctioning;

(7) modulation means for modulating the received combined subsplit signal; and

(8) second amplification means for amplifying and transmitting the combined subsplit signal onto the coaxial cable.

11. A routing terminator suitable for use in a communication system as claimed in any of claims 1 to 8 and comprising:

a. coupling means for coupling the routing terminator at a downstream end of a coaxial cable;

b. filter means for filtering and receiving a portion of a downstream signal;

c. demodulation and repeating means for demodulating and repeating a received portion of the downstream signal to generate an output signal having a larger signal to noise ratio than the received portion of the downstream signal; and

d. modulation means for converting the demodulated and repeated received portion of the downstream signal to a low frequency upstream signal.

12. A network interface unit suitable for using in a communication system as claimed in any of claims 3 to 8 and comprising:

a. coupling means for coupling the network interface unit to a drop cable;

b. first bandsplit filter means for

(1) receiving a combined signal from an active distribution unit via the drop cable, and

(2) separating an amplified extracted portion of a downstream signal and a predefined portion of an extracted portion of an upstream signal;

c. transmission means for

(1) transmitting the predefined portion of the extracted portion of the upstream signal to subscriber telephone equipment, and

(2) transmitting the amplified extracted portion of the downstream signal to subscriber video equipment;

d. reception means for

(1) receiving a new telephone signal from subscriber telephone equipment, and

(2) receiving a video control signal from subscriber video equipment;

e. second bandsplit filter means for

(1) combining the new telephone signal and the video control signal to form a combined subsplit signal, and

(2) transmitting the combined subsplit signal to the active distribution unit via the drop cable; and

f. control means for

(1) controlling receipt of a telephone signal being transmitted to the subscriber telephone equipment, and

(2) controlling transmission of the new telephone signal received from the subscriber telephone equipment.

13. A routing bridger suitable for use in a distributed communication system as claimed in claim 10 and comprising:

a. feeder band split filter means for

(1) receiving a high frequency signal from a feeder coaxial cable, and

(2) transmitting a low frequency signal to the feeder coaxial cable;

b. branch band split filter means for

(1) transmitting the high frequency signal to a plurality of network branches, and

(2) receiving a low frequency signal from each of the plurality of network branches;

c. data identifier means for

(1) identifying timing information for each of the plurality of low frequency signals received from the plurality of network branches, and

(2) generating a control signal for each low frequency signal;

d. control means for combining the plurality of low frequency signals received from the plurality of network branches into a single signal in response to the control signals generated by the data identifier means.

14. A method of providing combined telephone and video signal communications via a coaxial cable, the method comprising the steps of:

a. dividing a frequency spectrum of a coaxial cable into a low frequency subsplit channel and a high frequency supersplit channel;

b. transmitting combined video and telephone signals, in the supersplit channel, in a first direction from a central office toward a coaxial cable termination;

c. tapping off a predetermined portion of the video signal for transmission to subscribers;

d. amplifying the predetermined portion of the video portion to generate an amplified to-subscriber video signal;

e. converting, at a coaxial cable termination, a telephone portion of the combined video and telephone signals to a lower frequency telephone signal suitable for transmission in the subsplit channel, the converting comprising the steps of

(1) separating the telephone signal portion from the combined telephone and video signals being transmitted in the supersplit channel,

(2) demodulating the telephone signal,

(3) reconstructing the telephone signal to improve the signal to noise ratio of the telephone signal, and

(4) remodulating the reconstructed telephone signal using the lower frequency suitable for transmission in the subsplit channel;

f. transmitting the lower frequency telephone signal in the subsplit channel in a second direction from the coaxial cable termination back toward the central office;

g. tapping off the lower frequency telephone signal being transmitted in the subsplit channel for transmission to subscribers;

h. demodulating and selecting an appropriate portion of the tapped off lower frequency telephone signal to generate a to-subscriber telephone signal;

i. combining the to-subscriber video signal and the to-subscriber telephone signal into a single combined to-subscriber video and telephone signal; and

j. transmitting the single combined to-subscriber video and telephone signal to a subscriber via a drop cable.

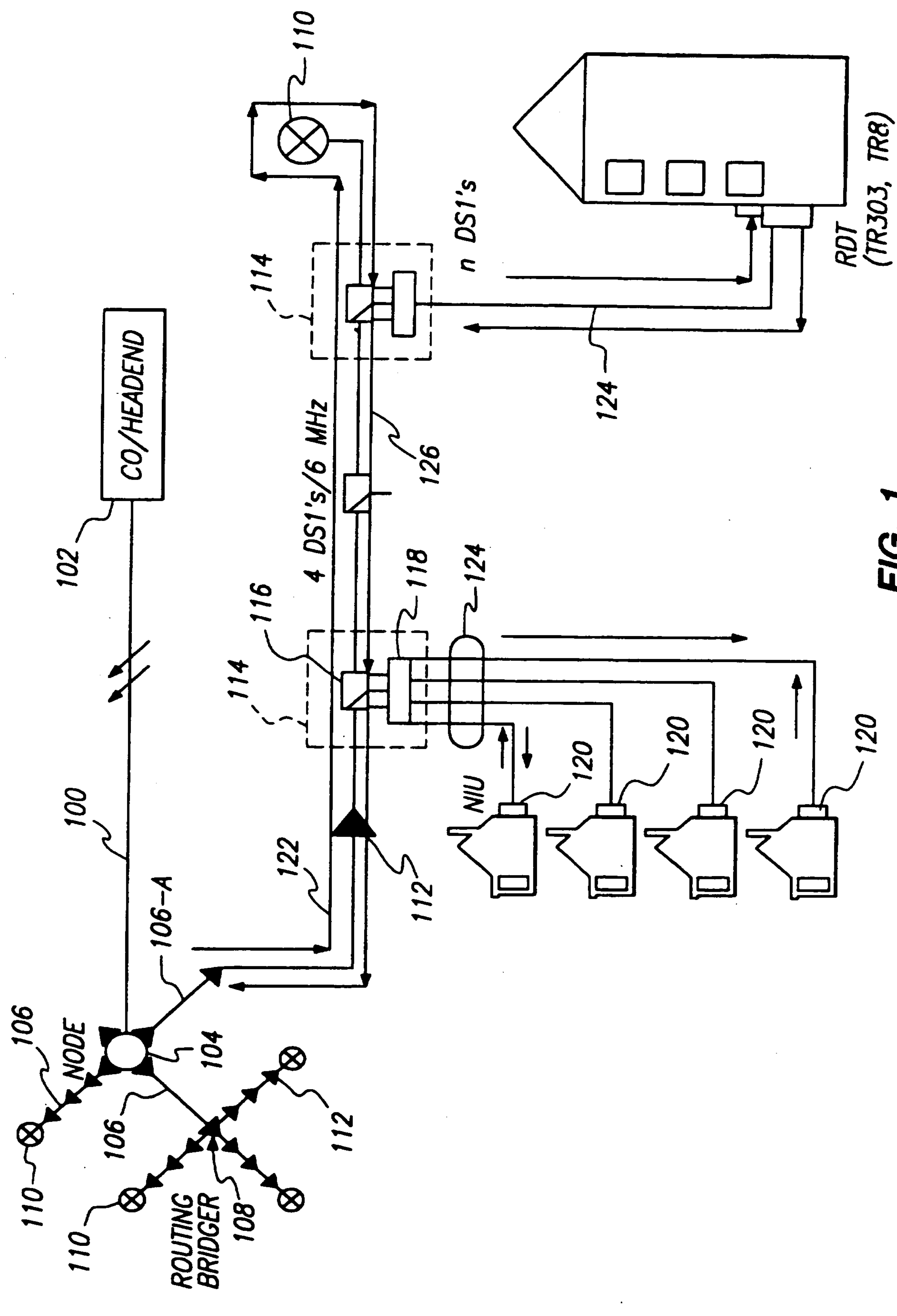
CO/HEADEND
102
100
106-A
NODE
104
106
110
ROUTING
BRIDGER
108
112
122
4 DS1's/6 MHz
126
114
116
118
124
NIU
120
n DS1's
RDT
(TR303, TR8)

FIG. 1

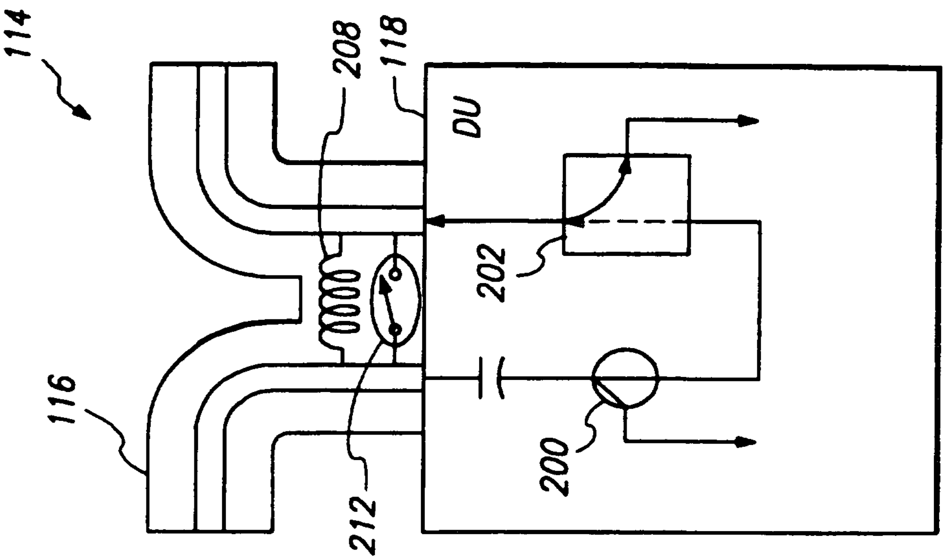
114
208
118
DU
116
202
212
200

FIG. 2B

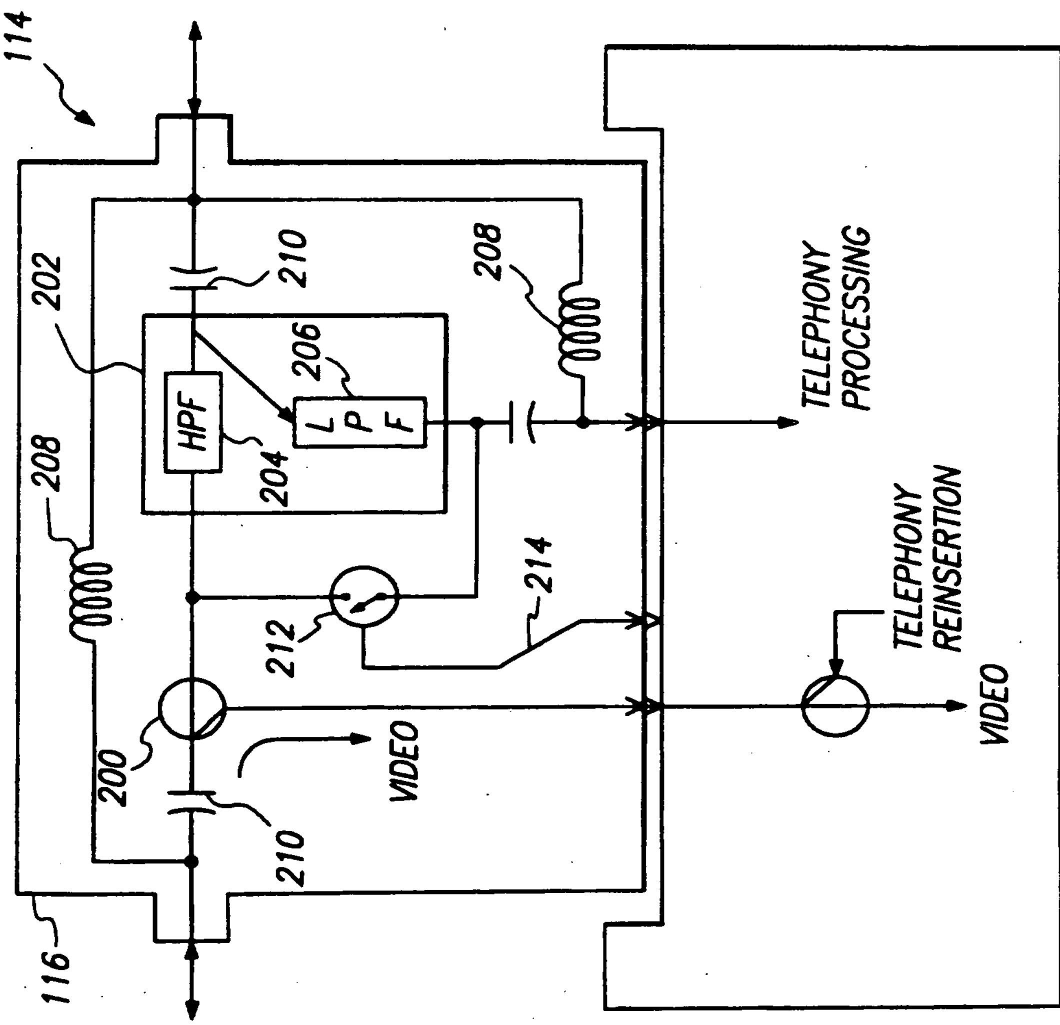
114
202
210
206
208
HPF
204
L
P
F
TELEPHONY
PROCESSING
118
212
214
TELEPHONY
REINSERTION
200
VIDEO
VIDEO
116

FIG. 2A

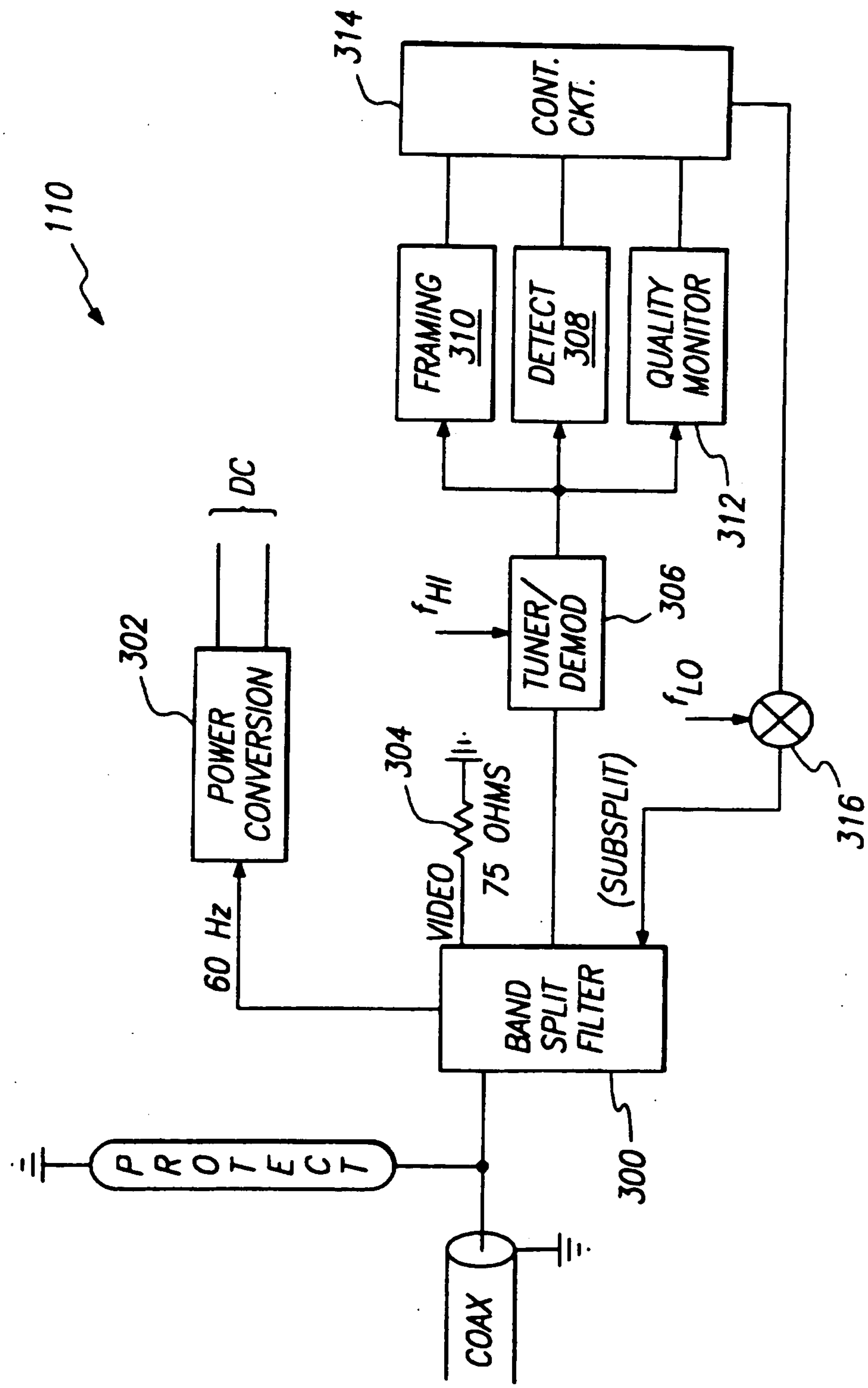
110
314
CONT. CKT.
FRAMING 310
DETECT 308
QUALITY MONITOR
312
DC
302
POWER CONVERSION
f_{HI}
TUNER/ DEMOD
306
f_{LO}
316
304
75 OHMS
VIDEO
(SUBSPLIT)
60 Hz
BAND SPLIT FILTER
300
PROTECT
COAX

FIG. 3

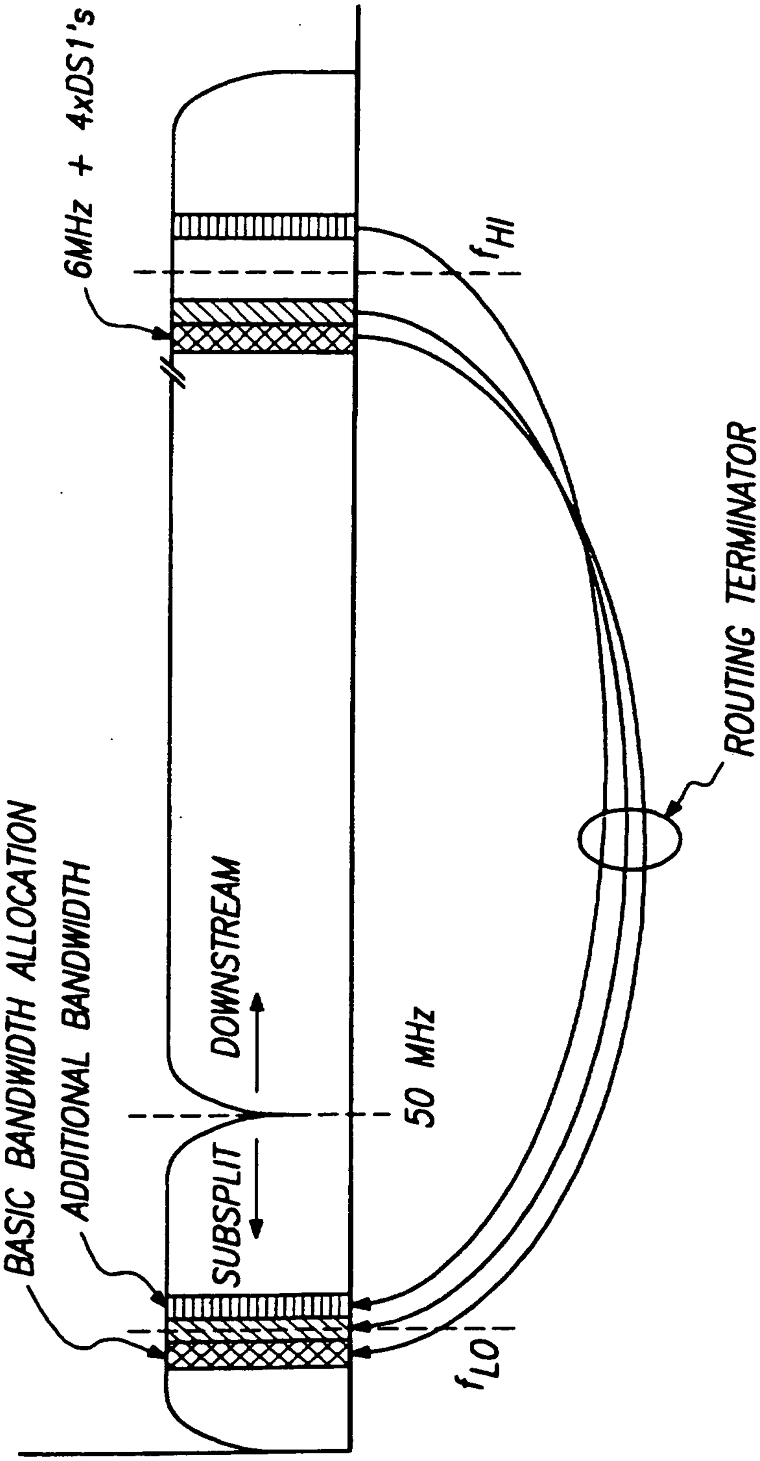
6MHz + 4xDS1's
f_{HI}
ROUTING TERMINATOR
BASIC BANDWIDTH ALLOCATION
ADDITIONAL BANDWIDTH
DOWNSTREAM
SUBSPLIT
50 MHz
f_{LO}

FIG. 4

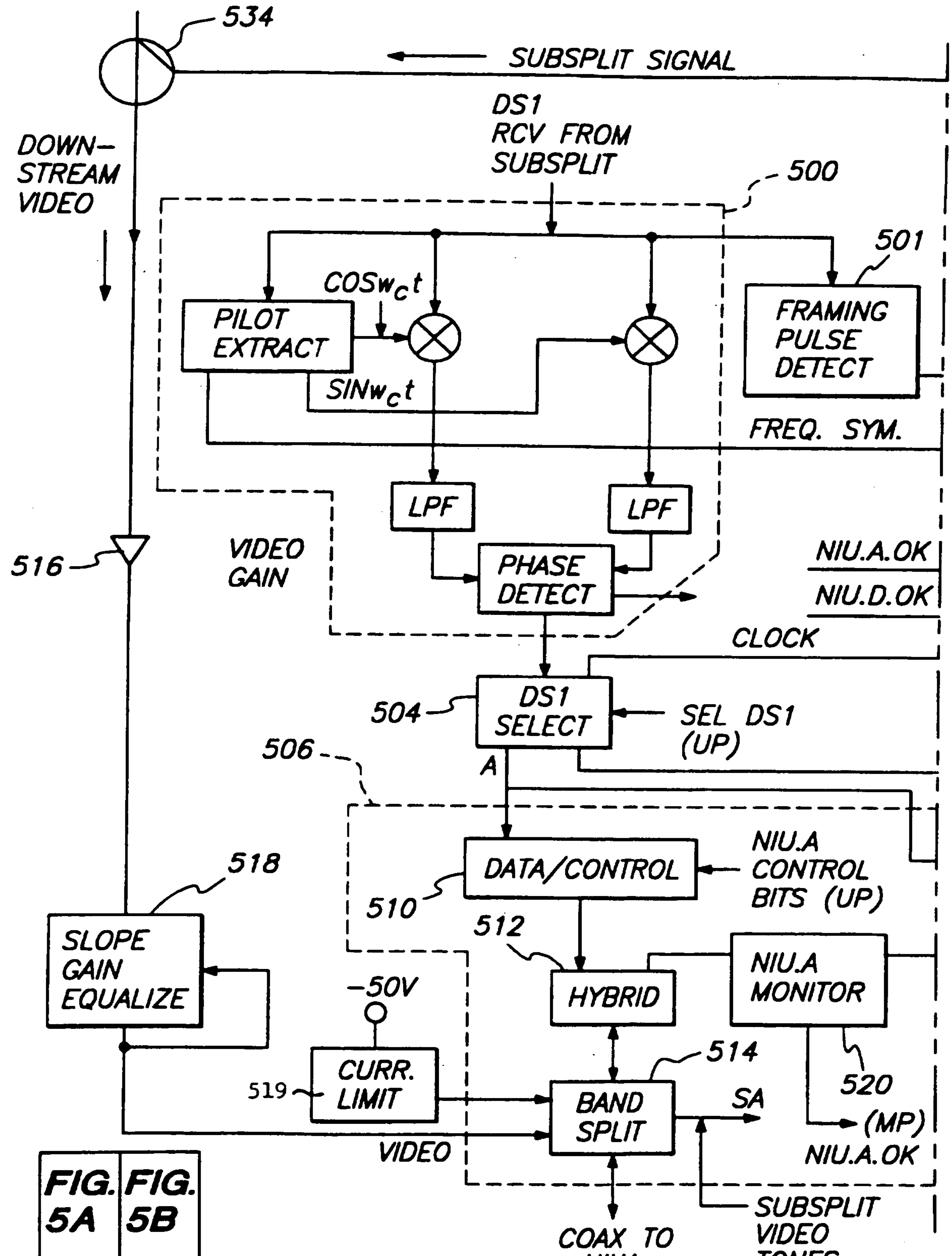
534
SUBSPLIT SIGNAL
DOWN-
STREAM
VIDEO
DS1
RCV FROM
SUBSPLIT
500
501
PILOT
EXTRACT
COSw_c t
SINw_c t
FRAMING
PULSE
DETECT
FREQ. SYM.
LPF
LPF
516
VIDEO
GAIN
PHASE
DETECT
NIU.A.OK
NIU.D.OK
CLOCK
504
DS1
SELECT
SEL DS1
(UP)
506
A
DATA/CONTROL
NIU.A
CONTROL
BITS (UP)
510
518
512
SLOPE
GAIN
EQUALIZE
HYBRID
NIU.A
MONITOR
-50V
CURR.
LIMIT
519
514
BAND
SPLIT
SA
520
(MP)
NIU.A.OK
VIDEO
COAX TO
NIUA
SUBSPLIT
VIDEO
TONES
FIG. 5A
FIG. 5B

FIG. 5

FIG. 5A

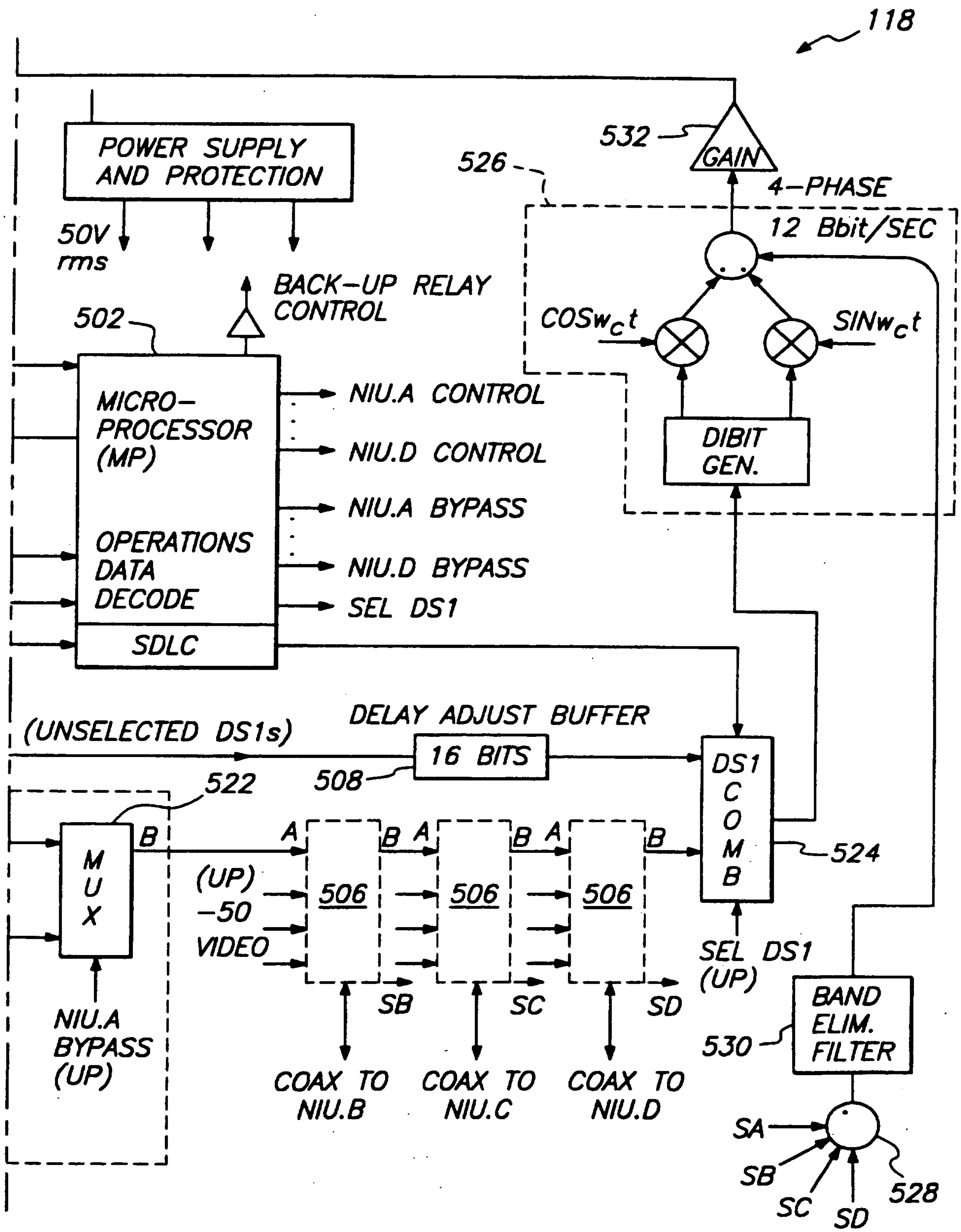
118
POWER SUPPLY AND PROTECTION
50V rms
BACK-UP RELAY CONTROL
502
MICRO-PROCESSOR (MP)
OPERATIONS DATA DECODE
SDLC
NIU.A CONTROL
NIU.D CONTROL
NIU.A BYPASS
NIU.D BYPASS
SEL DS1
532
GAIN
526
4-PHASE
12 Bbit/SEC
COSw$_c$t
SINw$_c$t
DIBIT GEN.
(UNSELECTED DS1s)
DELAY ADJUST BUFFER
16 BITS
508
522
MUX
B
A
(UP) -50 VIDEO
506
SB
SC
SD
DS1 COMB
524
SEL DS1 (UP)
NIU.A BYPASS (UP)
COAX TO NIU.B
COAX TO NIU.C
COAX TO NIU.D
BAND ELIM. FILTER
530
SA
528

FIG. 5B

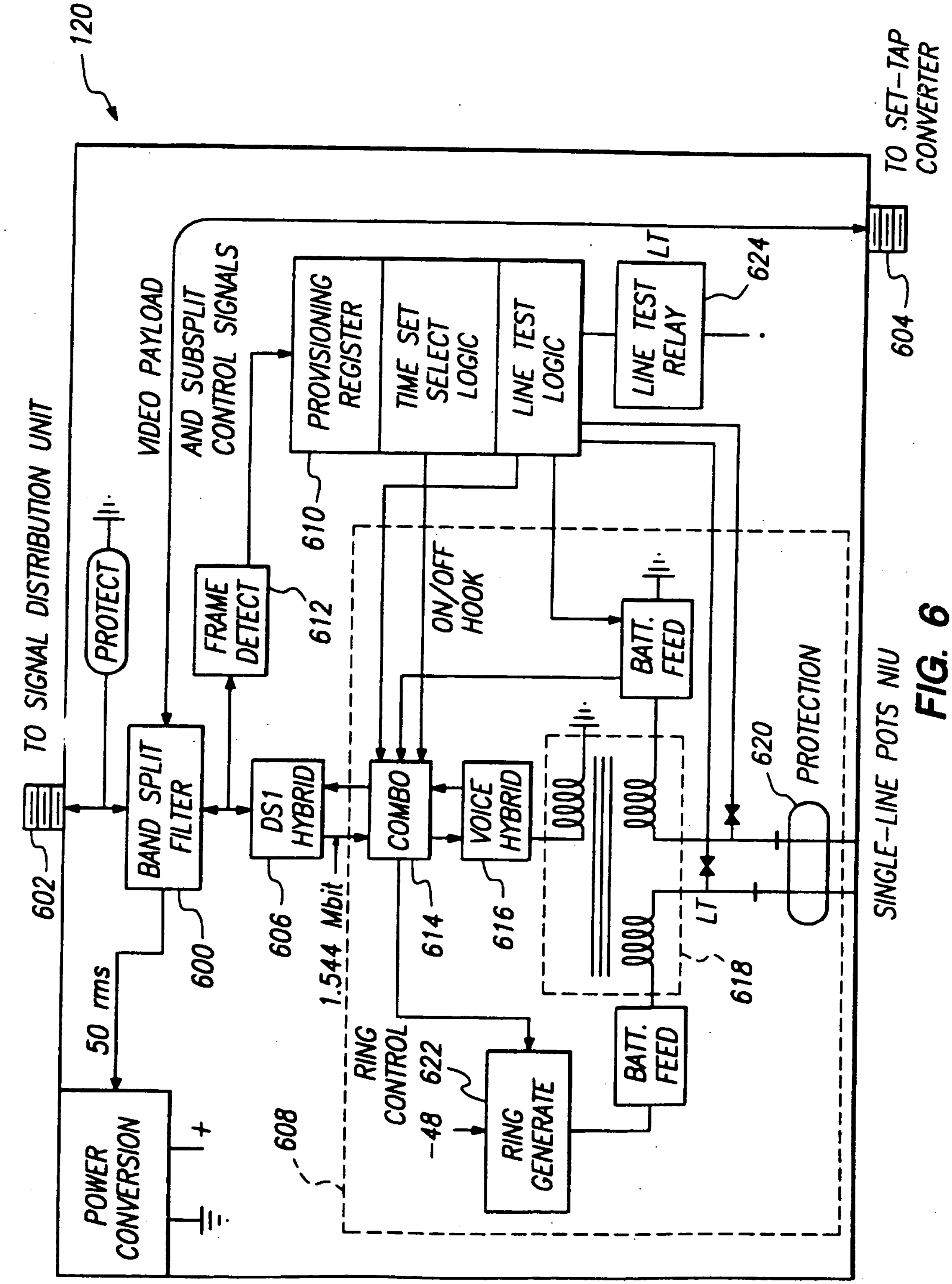
120
TO SIGNAL DISTRIBUTION UNIT
602
PROTECT
BAND SPLIT FILTER
600
50 rms
POWER CONVERSION
+
VIDEO PAYLOAD AND SUBSPLIT CONTROL SIGNALS
FRAME DETECT
612
DS1 HYBRID
606
1.544 Mbit
PROVISIONING REGISTER
TIME SET SELECT LOGIC
LINE TEST LOGIC
610
ON/OFF HOOK
COMBO
614
RING CONTROL
622
-48
RING GENERATE
608
VOICE HYBRID
616
BATT. FEED
BATT. FEED
618
LT
LINE TEST RELAY
LT
624
620
PROTECTION
SINGLE-LINE POTS NIU
TO SET-TAP CONVERTER
604

FIG. 6

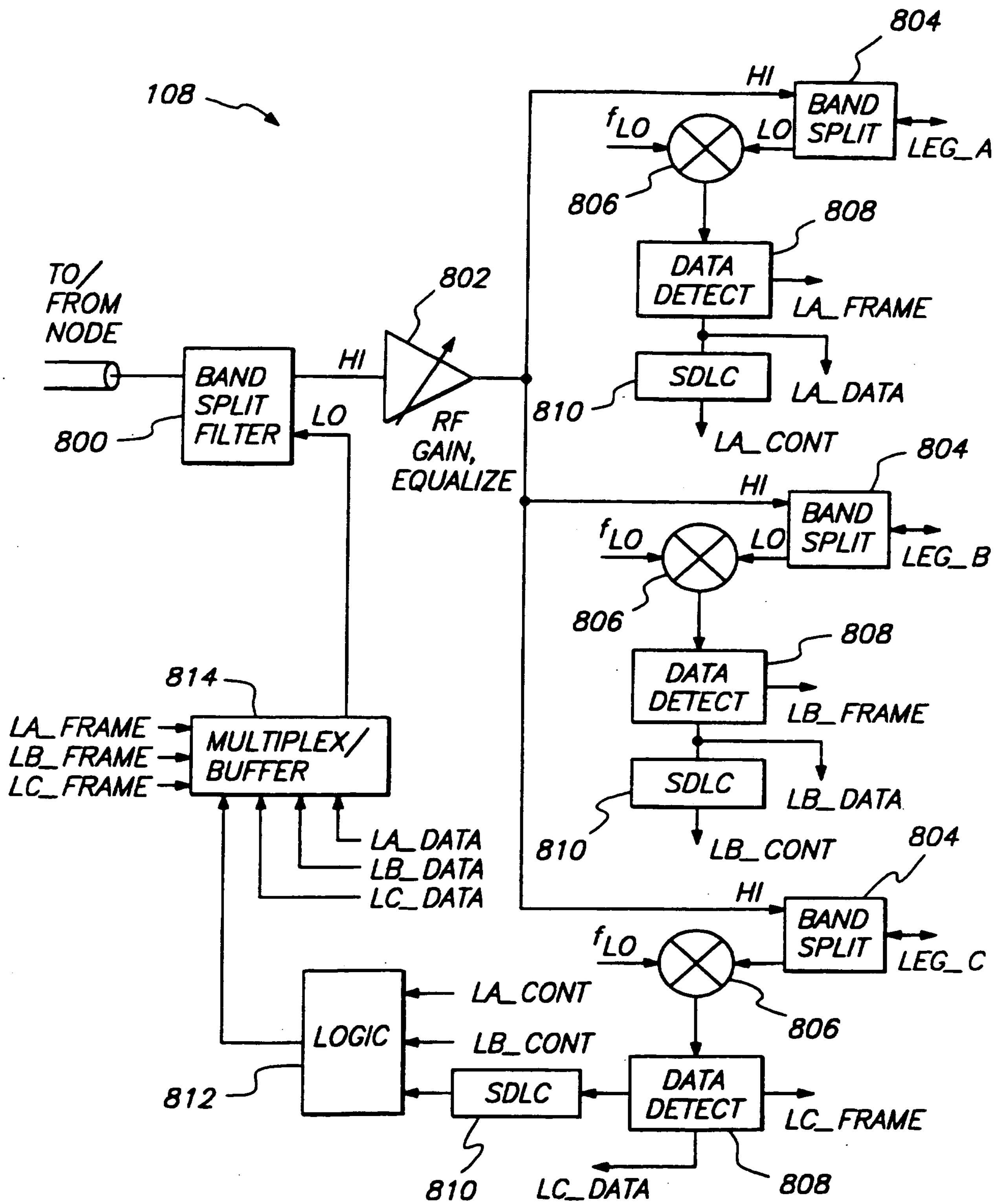
108
804
HI
BAND SPLIT
f_{LO}
LO
LEG_A
806
808
DATA DETECT
LA_FRAME
TO/ FROM NODE
802
HI
SDLC
LA_DATA
810
BAND SPLIT FILTER
LO
RF GAIN, EQUALIZE
LA_CONT
800
804
HI
BAND SPLIT
f_{LO}
LO
LEG_B
806
808
DATA DETECT
LB_FRAME
814
SDLC
LB_DATA
LA_FRAME
LB_FRAME
LC_FRAME
MULTIPLEX/ BUFFER
LA_DATA
LB_DATA
LC_DATA
810
LB_CONT
804
HI
BAND SPLIT
f_{LO}
LEG_C
LOGIC
LA_CONT
LB_CONT
806
812
SDLC
DATA DETECT
LC_FRAME
810
LC_DATA
808

FIG. 7

INTERNATIONAL SEARCH REPORT

Inte onal Application No
/US 95/15866

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04L12/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04L H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US-A-5 361 394 (SHIGIHARA) 1 November 1994 see column 1, line 10 - line 35 see column 3, line 7 - line 37 see figure 1 ---	1-3,5,7, 9,10,12, 14
A	US-A-5 124 980 (MAKI) 23 June 1992 see column 2, line 29 - line 45 see column 4, line 17 - line 36 see column 4, line 62 - column 5, line 21 see column 6, line 35 - line 59 see column 7, line 15 - line 56 see column 25, line 9 - line 67 see figures 1,2 --- -/--	1-3,5, 7-10,12, 14

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

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Date of the actual completion of the international search: 24 April 1996

Date of mailing of the international search report: 09.05.96

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Fax: (+ 31-70) 340-3016

Authorized officer: Vaskimo, K

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CATV SESSIONS, 17 June 1989 - 22 June 1989 MONTREUX, CH, pages 415-425, XP 000093815 SUDHIR GUPTA 'Application of return channel for telecommunication' see page 415, line 2 - line 5 see page 416, line 4 - line 19 see page 417, line 4 - page 418, line 10 see page 419, line 1 - line 13 see page 422, line 4 - line 7 see figures 1,2 ---	1-5,7, 9-12,14
A	IEE PROCEEDINGS, vol. 134, no. 1, January 1987 STEVENAGE, GB, pages 1-8, F. HALSALL, D. SIROVICA, S.M. HARRISON 'FAMNET : an integrated voice and data network' see page 1, left column, line 2 - line 18 see page 1, right column, line 1 - line 5 see page 1, right column, line 29 - line 51 see page 2, right column, line 44 - page 3, left column, line 32 see figures 1,3 -----	1-7,9-14

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 95/15866

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-5361394	01-11-94	JP-A- 3188784	16-08-91
US-A-5124980	23-06-92	NONE	